Use of a Risk-Based Decision Process in the Design of CSO Control Strategies for an Urban Estuarine Watershed

Sydney Munger
King County Department of Natural Resources

Betsy Adamson, Scott Mickelson, Kevin Schock, Randy Shuman, Jim Simmonds, John Strand, Bob Swarner, Laura Wharton, and Kathryn White
King County Department of Natural Resources

John Toll and Charles Wisdom
Parametrix, Inc.

Introduction

The King County Department of Natural Resources is conducting a Water Quality Assessment for the Duwamish River and Elliott Bay, which lies in an urbanized, industrialized watershed in Seattle, Washington. The purpose of the Water Quality Assessment is to provide information for making decisions about the future of King County's combined sewer overflow (CSO) control program. This effort was motivated by the State of Washington's adoption of a long-range standard for CSO control of one uncontrolled overflow per discharge point in a year of average rainfall. The long range planning process for wastewater treatment in King County has estimated the cost of achieving this standard to be $600 million.

The first objective of the Water Quality Assessment is to understand the existing conditions of the Duwamish River and Elliott Bay in terms of level of risk to aquatic life, wildlife, and people who use this estuary. Under this objective we want to answer the following questions:

- What populations of aquatic life and wildlife live in this estuary?
- How many and what types of people use the estuary, and how do they use it?
- What concentrations of chemicals are present in the water and sediments and living tissues that could harm aquatic life, wildlife and people (the receptors)?
- What other physical and biological stressors are present in the River and Bay that could harm these same receptors?
- What is the level of risk to these receptors from chemical, physical, and biological stressors in the system?
- Which stressors are the most significant?

A second objective of the Water Quality Assessment is to understand the significance of CSO stressors compared to those from other sources. The following questions will be addressed under this objective:

- What proportion of chemical, physical, and biological stressors in the river and bay result from CSOs?
- How much will aquatic life, wildlife, and human health risks be reduced by elimination of CSOs?
- Which stressors are the most significant?

A third objective is to facilitate stakeholder input to key decisions on where and how to focus regional efforts to protect the river and bay.

The fourth objective is to provide a tool for watershed-level assessments. Under this objective we want to answer the following questions:

- Can risk assessment be used in identifying the most significant stressors in a watershed?
- Can a hydrodynamic model for the estuary be extended for use throughout the watershed?

The final objective is to provide a scientific basis for decisions on project prioritization and control technologies utilized for the County's CSO control program.

Methodology

The methods for ecological and human health risk assessment designed by the US Environmental Protection Agency (EPA 1989; 1992; 1994, 1996) and the Water Environmental Research Foundation (Parkhurst et al. 1996) are being used to describe potential risks to aquatic life, wildlife, and people who use the Duwamish River and Elliott Bay, and how the risks could change with control of CSOs.

A model that predicts the concentrations of chemical stressors and other potential changes in the water body will drive the risk assessment. The model is essential to predict conditions in the estuary if CSOs are eliminated. The model also provides a way to fill gaps in data on current conditions. A sampling program that allows model calibration and detailed characterization of the physical, chemical, and biological stressors entering the Duwamish River/Elliott Bay ecosystem supports the modeling effort.

Stakeholder Committee

The project team recognized early that to achieve our objectives, a major component of our work would be focused on supporting, educating and listening to people from the region who have a stake in the outcome. We also realized that because this is a complex project, in which highly technical information will be used to make policy-level decisions, it would be necessary to work with a committed group of stakeholders from the beginning to allow them to learn the process and be able to provide significant input.

Who are the Members?

The committee includes 28 individuals from government agencies, Native American tribes, community councils, environmental groups, businesses and industries. This committee includes individuals who work in the environmental field and are technically able to advise the project team, as well as community leaders who are aware of the issues and share a vision for how the resource could be in the future. The quality of the project and the usefulness of the final product will be much greater because of the involvement of this committee from the beginning.

What is the Role of the Committee?

The role of the committee is to (1) provide input to the design of the risk assessment and (2) provide recommendations to King County on key decisions that are discussed in the next section.

What Process was Developed to Give and Receive Input?

Work with the stakeholder committee has centered on full-day workshops with the whole committee, and half-day working sessions with a technical subcommittee of self-selected members, interested in participating in greater depth on a specific topic. To date we have held three full-day workshops and five half-day working sessions. Additional working sessions are scheduled monthly through project completion. The first workshop described the project and the role of the committee. We also asked the members to describe in writing their vision for the Duwamish River and Elliott Bay, which was subsequently helpful in developing the management goal and guiding the selection of assessment endpoints. The second workshop focused on the problem formulation and receiving input on the assessment endpoints. In the third workshop we presented the plan for the risk assessment and asked the stakeholders for help obtaining information about how people use the estuary. The fourth workshop will be held in April and will be two full days. At this workshop the results of the risk assessment will be presented and the stakeholders will develop their recommendations to King County regarding the CSO control program.

Risk Assessment

Why Risk Assessment?

The challenge for King County was to find an approach to this assessment that would allow us to quantify and characterize the harm that may be occurring to aquatic life, wildlife, and people who use the resource; and how the likelihood of that harm would be changed with the control of CSOs. The process of ecological and human health risk assessment provides such an approach.

Dialogue with King County Management and the Department of Ecology resulted in agreement that a risk assessment approach would provide a means of describing the benefits to be achieved by controlling CSOs. The outcome of the CSO assessment may demonstrate that the benefits of control are significant; alternatively, it may show that the expected benefits will be minor. In either case it is expected that the assessment will help identify project priorities and appropriate CSO control technologies that maximize improvements to the study area.

What is the Goal for the Duwamish River and Elliott Bay?

The first task in planning for a risk assessment is to develop a management goal for the resources being assessed. In this Water Quality Assessment, the resources are the lower Green and Duwamish River and Elliott Bay. The WQA project team and consultants using information heard at the Stakeholder Workshop in November 1996, as well as information from King County Managers developed the following management goal:

> Design a CSO control strategy whose goal is to continuously protect and improve water, sediment and habitat quality. Indicators of achieving this goal are abundant, diverse and healthy biological communities and enhanced recreational, commercial, and cultural use of the resources.

Decisions will be made by the King County Executive, King County Council and the Washington State Department of Ecology after considering the recommendations of the regional stakeholders. The Stakeholder Committee for this project will submit a written report containing recommendations on CSO control to the King County Executive. The ultimate decision-maker will be the Department of Ecology.

There are a series of decisions that will be based on the outcome of this study. These include answers to the following questions:

- Is the CSO contribution to human and ecological health risks significant? Why or why not?
- If the CSO contribution is not significant, what should be the next steps for the CSO control program?
- If the CSO contribution is significant, what CSO control scenario does King County recommend to the Department of Ecology? Are there other recommendations on how to meet the management goal for this estuary?

Water Quality Modeling

The water quality assessment team has opted to create a mathematical model of the Duwamish Estuary and Elliott Bay that will predict where chemicals from various discharges travel in these water bodies. The Duwamish River-Elliott Bay model has two components. The first is a hydrodynamic model that describes the water flow; the second is the chemical and bacteria fate and transport model that describes the addition, removal, movement and behavior of chemicals and bacteria in the study area including those that reach the sediments.

The model will be run with CSO inputs as they are now, to represent current conditions, then run again without CSO discharges. The physical area covered by the model includes the Green/Duwamish River from the Interstate 405 bridge to the outer bounds of Elliott Bay near Alki Point. The model divides this area into 500 cells, and divides the depth into 10 layers; thus, the model can realistically simulate how chemicals from the CSOs and the other sources are distributed to 5,000 locations within the Duwamish River and Elliott Bay estuary ecosystem.

Field data were collected to support development and verification of the model. Data collected to support the water flow portion of the model included Elliott Bay and Duwamish River information from water level sensors, meters that measure the speed and direction of water movement, and automated meters that record water temperature and salinity. The chemical and bacterial portions of the model were developed and verified with data taken from 39 water stations on a weekly schedule of non-storm samplings and more frequent sampling associated with storms. Most of these stations were grouped adjacent to CSOs, with three surface/subsurface pairs of stations located across the river. A station was located upstream of the study area to measure inputs to the study area from the river and a corresponding station on the Puget Sound boundary of the model. At these stations measurements were taken for conventional parameters such as nutrients and oxygen concentrations, as well as bacterial numbers, metals, and organic chemical concentrations. Sediment analyses included concentrations of metals, organic chemicals, and physical characteristics such as sediment particle size.

A crucial piece of information in the building of a fate and transport model concerned with CSO impacts was the collection of CSO samples during storm events. Automated samplers were installed in five of the most active CSOs in the study area. These samplers collected water samples both as sequential discreet samples and as composite samples. These samples were analyzed for the same parameters as the water and sediments and the data used as CSO inputs to the model.

To ensure the model provides accurate information to the risk assessment, the model coefficients were calibrated to accurately predict study area hydrodynamics and field data concentrations. The calibrated model was verified with an independent set of field data to test its performance under a different set of conditions. The calibrated and verified model is used to predict how chemicals from various sources are transported through the Duwamish Estuary and Elliott Bay, providing a surrogate for a large-scale field-monitoring program for estimating chemical concentrations at particular sites for use in the risk assessment.

Using Model Output in the Risk Assessment

The successfully calibrated and verified model will be used to estimate chemical concentrations in the water column and sediments throughout the study area. The current conditions and zero-CSO concentration data will be used in the risk assessment to estimate direct exposures to water and sediment-borne stressors. The differences between stressor concentrations under these two situations will give an estimate of the CSO contribution to the chemical and bacterial concentrations in Duwamish River and Elliott Bay waters and sediments. The differences between risks estimated for current and zero-CSO conditions will represent the CSO contribution to risks.

The model will not be used to estimate tissue concentrations in fish, shellfish, and invertebrates that could be eaten by aquatic life, wildlife, or people. Instead, exposures from eating seafood will be estimated using tissue concentration data from fish and crabs collected in the study area. The model will be used to estimate the reduction of fish and shellfish exposures under the zero-CSO scenario relative to current conditions. This will provide an estimate of the CSO contribution to risk from seafood consumption.

Estimating Risks

Risks to people will be estimated for two pathways: (1) direct contact with chemicals and pathogens in Duwamish River and Elliott Bay sediments or waters, and (2) exposure to chemicals or pathogens from eating seafood or incidentally ingesting sediment or water. We will estimate risks for a variety of exposure "scenarios" to try to represent the range of human uses of the estuary. The chemical exposure estimates will be compared to toxicity reference values and slope factors developed by the U.S. EPA to estimate whether and which chemicals from CSO and non-CSO sources are potentially causing risks to people. Pathogen exposure estimates will be compared to minimum infective dose estimates from the scientific literature to assess the potential pathogen risks.

Risks to wildlife will be estimated using methods similar to those for estimating risks to people. The exposure pathway to be assessed in the wildlife risk assessment is exposure to chemicals from ingesting prey and Duwamish River and Elliott Bay waters. Exposure estimates will be based on a combination of site-specific data and wildlife exposure factors (things like how much food wildlife eat, the areas over which they range, etc.) taken from the scientific literature. The exposure estimates will be compared to toxicity reference values derived from the scientific literature, to estimate whether and which chemicals from CSO and non-CSO sources are potentially causing risks to wildlife. The wildlife risk assessment will use probabilistic methods to estimate and evaluate the uncertainties about wildlife exposure levels and toxicity reference values. The wildlife risk assessment will also evaluate changes in habitat or water quality parameters (i.e., changes due to sedimentation or scouring, decreases in dissolved oxygen levels, increases in water temperature, or decreases in salinity) that adversely affect wildlife use of the Duwamish River and Elliott Bay.

Potential risks to the aquatic ecosystem from exposures to physical and chemical stressors will be assessed by comparing peak sediment and water concentrations, by location, to a distribution of toxicity reference values (concentrations at which specifically defined toxic effects begin to occur) representing different aquatic taxa, using the methodology of the Water Environment Research Foundation (WERF). The results will be estimates of the fraction of aquatic taxa potentially at risk at each location, compiled to form a probability distribution of the percent taxa potentially at risk. The advantage of the WERF methodology over a traditional "risk ratio" (i.e., exposure concentration divided by toxicity reference value) is that the distribution of percent taxa potentially at risk is a more meaningful interpretation than a risk ratio. The former indicates the consequences (i.e., the percent taxa potentially at risk) of observed exposure levels, whereas the latter simply indicates the factor by which observed exposure levels exceed threshold concentrations (i.e., a sensitive species' toxicity reference value), without information about the ecological significance of the observed exceedances. In addition to estimating risks by the WERF methodology, water column and sediment bioassay and benthic community survey data will be assessed to provide additional lines of evidence regarding the level of potential risk to the aquatic ecological community due to CSO and non-CSO sources of physical and chemical stressors.

Conclusion

We have completed the field sampling, configured the model, and prepared the data for entry into the model. We have had three of five workshops with the stakeholder committee and two of three workshops with the WERF peer review panel. We continue to hold working sessions with the stakeholder committee on a monthly basis. Current plans are to complete the Water Quality Assessment of Elliott Bay/Duwamish River in mid-1998.

Once the Water Quality Assessment is completed, King County will work to better resolve non-CSO (stormwater runoff, non-stormwater point sources, existing sediment contamination, and groundwater) source contributions to risks in the Duwamish estuary. In addition, the County intends to conduct a risk-based evaluation of specific source control scenarios using the water quality model. The application of similar risk-based decision processes to other management problems in the Duwamish estuary and other King County watersheds is being considered at this time.

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